HCAL Pulse Shape

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Simulation of HCAL Electronics

Pulse shape generation & interpretation

- Beam parameters
- Shower in scintillator layers
- Wavelength shifting in fibers
- Transport to photodetector
- Photodetector response
- QIE response
- FADC conversion

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Beam Parameters

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Size of the luminous region

- Crossing angle and transverse beam size determine size of the luminous region
- So small, 5cm rms, no effect on calorimeter

Duration of each crossing

- Longitudinal beam distribution determines interaction rate versus time
- Gaussian with a mean = 0 (by definition) and sigma < 1 nsec
- No effect on calorimeter

Shower Sampling

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Time of flight to first interaction

- B-field is necessary
- Time varies with eta – taken out in hardware
- Time jitter distribution is exponential
- Most showers begin in the crystals

Scintillator samples shower development

- Very fast response, ~2.5 nsec time constant
- Readout has depth segmentation with a different calibration for each compartment
- "Tail-catcher" compartment is not included in the Level 1 trigger sum – available for HLTs

WLS Fiber Readout

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Wavelength shifting fibers in every tile

- Length of the fiber varies with eta, ~7 nsec
- Time constant of the fluor is ~12.5 nsec
- Efficiency of conversion is ~5% so Poisson fluctuations are important for both pulse shape and length at low energies, <1 GeV

Clear fibers from tiles to photodetectors

- Each layer in depth has a different length of fiber, partially compensated (beta=1/2c)
- Eta dependence of average length taken out in the hardware (along with time-of-flight)
- Some light is lost here as well

Photodetector Response

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Quantum efficiency

- Typically about 12%
- Changes the point where Poisson shape fluctuations are important to E < 10 GeV
- Thick compartment: 10 photoelectrons/GeV

Time response

- Determined by the reverse bias voltage
- Different for 19-pixel and 73-pixel devices because of capacitance
- May be fast enough that convolution with the photoelectron distribution isn't needed except at low energies.

Simulation Logic - 1

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Pick t-zero

- Gaussian with mean = 0, sigma =

Track particle(s) to first interaction

- B-field on
- Keep track of time

Shower development

- Layer by later deposition of energy in scintillators
- Keep track of times of deposition layer by layer, Tscint., in 2 nsec bins

Simulation Logic - 2

WLS fiber photon distribution

- Convert E to N photons for each scintillator layer using Poisson statistics
- Draw N(E) photons from the wls fiber filling time distribution (geometry + exp(-t/12.5 nsec)
- Use Tscint as the filling function start time
- Propagate photon pulse to the HPD including the mirror on the far end and attenuation
- Look up table of delta-time for each scintillator

Sum over depth segments

- Add up the photon pulses from all layers in the depth compartment in 2 nsec bins

Simulation Logic - 3

Convert to photoelectrons

- For each photon, draw from a Poisson probability for conversion with mean 12%

Convert to photodetector pulse

- Convolute photoelectron pulse with the impulse response function of the HPD

Convert to QIE analog pulse

- Convolute HPD pulse with the impulse response of the QIE - which is amplitude dependent

Simulation Logic - 4

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Integrate into time slices

- Using the time offset (+ or -) determined at the point where the photoelectron distribution was created, integrate the pulse in 25 nsec intervals.
- The nominal time offset has the pulse starting 5 nsec into the first 25 nsec interval to allow for early fluctuations

FADC the integrated values

- Use a look up table for the FADC floating point transfer function – range and mantissa

Simulation Logic - 5

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Linearize the FADC results

- Use a lookup table giving 16-bit integers

Generate trigger primitives

- Add layer 0 to the main compartment
- Use a sliding 5 time-sample window to extract the energy, weights: -1.5, -1.5, 1.0, 1.0, 1.0
- Use a lookup table to transform the TPG results according to the Level 1 compression algorithm de jour

Generate HLT data

- Issue is improved energy estimate for zero suppression

Note re Forward Calor.

HCAL

Sampling is based on Cerenkov light generated in quartz fibers

Photodetector is a photomultiplier tube

Intrinsically fast

- At the PMT, pulse is ~10 nsec at the base
- Simulation of cable and QIE analog section shows pulse is over within one 25 nsec clock interval
- No pile up from prior beam crossings
- Only have the intrinsic pile up from multiple hits in a tower from the same beam crossing

Previous Experimental Data on Photodetectors by HF Group

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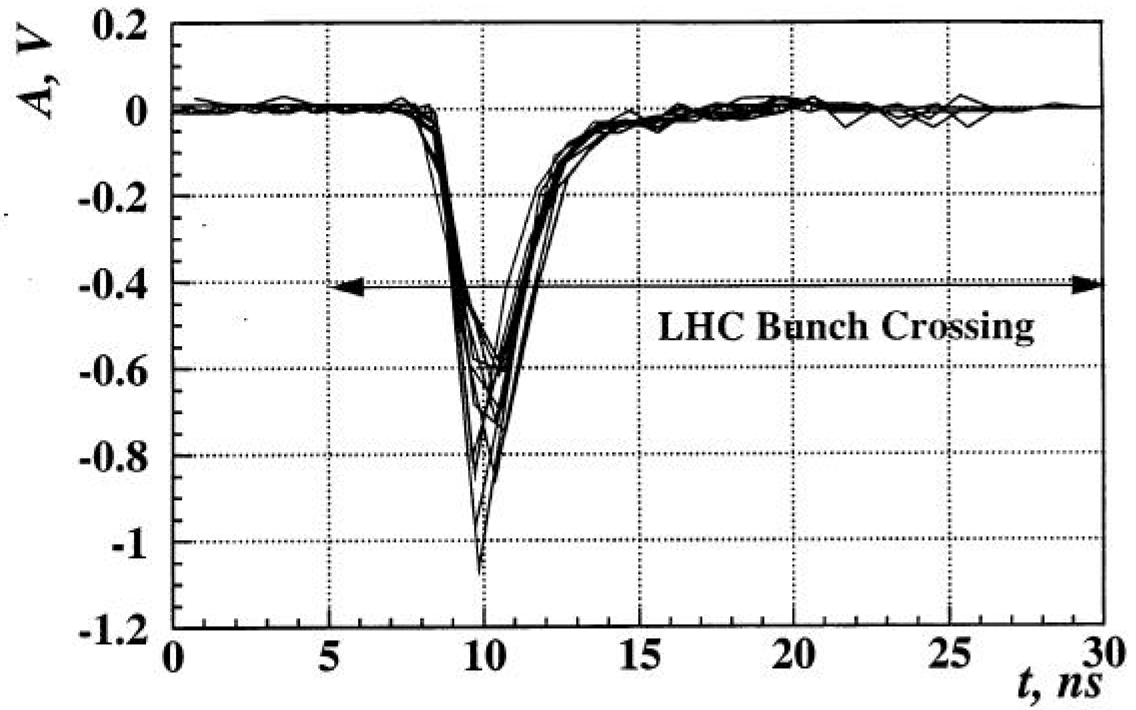
R6427

350 GeV Pion Signal



Now vs. Later

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Test beam measurements later

- Planned for summer of 2002

Interim possibility now - simplify

- Based on estimates that show fluctuations in time and area due to shower development and time jitter are far smaller than the resolution – 100% at 1 GeV, 30% at 10 GeV:

- Add all of the scintillator light in a given compartment, ignore timing details
- Use a universal pulse shape
- Use photostatistics of the HPD

Summary

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Energy is the sum of three consecutive time samples

- E = total charge in the pulse (minus baseline)

Low energies will be a problem for:

- Identifying the correct crossing (shape fluct.)
- Pile up at high luminosity

Pulse shape is only an estimate

- Open issue re possible neutron induced tail
- Layer to HPD time-of-arrival distribution put in crudely as a rectangular smearing

Priorities to ORCA

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1. Digitizations

- **HF**
  - Fast - crossings are independent
- **HB and HE**
  - Replace pulse shape FADC sampling with pulse integration FADC values

2. Photostatistics

- **HF, HB and HE**
  - Depth compartments - need pe/GeV numbers
  - Draw N(E) photoelectrons from a Poissan

Priorities to ORCA

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3. Pedestal and noise

- **Pedestal is an electronic offset from FADC = 0**
- **Marks the position of zero energy**
  - E = E(FADC) - E(Pedestal)
- **Noise is 4000 electrons sigma**
  - Equivalent to 2 photoelectrons HB, HE, HO
  - Equivalent to 0.1 photoelectrons HF
- **FADC bin size is 6000 electrons**
  - Equivalent to 3 photoelectrons HB, HE, HO
  - Equivalent to 0.15 photoelectrons HF

Studies

Trigger primitive generator algorithm

- Energy extraction options
- Bunch crossing identification options
- Remember the latency constraint

Zero suppression algorithm

- Energy extraction options
- Bunch crossing already known
- “Sharp” threshold desired

Phase of the beam clock

- Relative timing between cal pulse & beam
- Optimum maay depend on luminosity